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EFFECT OF WATER-CEMENT RATIO ON THE STRENGH PROPERTIES OF QUARRY-SAND CONCRETE (QSC)

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ABSTRACT
This paper presents the empirical results of the effect of water-cement-ratio (W/C) on the strength properties of Quarry sand concrete (QSC). The investigation reveals the pattern of relationship between W/C and compressive strength. Two nominal mix proportions of 1:2:4 and 1:3:6 (Cement-Quarry sand-Gravel) showed that compressive strength decrease with increased W/C. The maximum strength of 23.71N/mm^2 was achieved with mix proportion of 1:2:4 and W/C of 0.5 at 28days hydration. All mixes used in the study attained over 60% of their 28 day strength at 7 days.

KEYWORDS: Quarry-Sand, Concrete, water-Cement-Ratio, Mixes, Strength.

INTRODUCTION

During the past decade, extensive international research on concrete materials technology has resulted in the emergence of new competitive materials technology: for instance high performance concrete (HPC) and self compacting concrete (SCC), Walraven (1999). The use of concrete for various construction works has in recent time led to the escalation in the cost of construction materials particularly cement and aggregate. Aggregates which occupy 70-75% of the total volume of mass concrete (Troxel *et al* 1968) has been one material, which if alternatives are provided will bring down the overall cost of construction (Kamang and Umoh 2005). Investigations into the development of new construction materials are being conducted every day with the view to either replacing or using in combination with the conventional materials. As reported by (Kamang and Umoh 2005), locally sourced products such as palm kernel shell, olive seeds and broken bricks have been used as aggregates in concrete production by Okpala (1990), Datok and Kamang(1998) and Maher (1987) respectively. The use of materials other than natural sand as fine aggregate in both concrete and motar has also been investigated. Among these materials are silt and kaolin waste by Banfill and Benson 1978, laterite by Lasisi *et al* (1990), waste Sancrete blocks by Kamang and Umoh (2005) and Quarry sand by Waziri and Muazu (2008). With the recent trend towards utilization of locally sourced building material so as to reduce construction cost and the availability of quarry sand from quarry sites across the country has brought about the research. To achieve maximum utilization of quarry sand in concrete production, it is imperative to adopt a suitable mix proportion for specified strength; this implies the selection and proportioning of various concrete constituents (cement-quarry sand-gravel) in order to produce as economically as possible concrete of definite required properties such as consistence, strength and durability. Furthermore, water-cement-ratio (*W/C*) which is about the most important parameter in determining concrete strength needs to be carefully controlled as any increase beyond the specified value leads to strength reduction among other adverse influence on the concrete properties (Adeagbo 1999). From previous studies it is evident that the strength attained by concrete is greatly influenced by the water-cement ratio (*W/C*), therefore the need to investigate this property (*W/C*) and its interaction with other performance characteristics of Quarry sand concrete requires no further emphasis.

This study, thus, aimed at investigating the effect of water-cement-ratio (*W/C*) on the compressive strength of quarry sand concrete (QSC). It tries to establish the optimum *W/C* for the production of medium grade QSC using the nominal mix proportions of 1:2:4 and 1:3:6.

RESEARCH METHODOLOGY

The quarry sand used for the experiment was obtained from a quarry site in Gwoza, Borno State. The aggregates were thoroughly washed (to remove unwanted materials) and dried; they were graded in accordance with BS 812 part 1: 2002. The cement used is the Ashaka brand of ordinary Portland Cement (OPC). Its initial and final setting time was determined using BS 12: (2002). Water used for the tests was free from impurities such as silt, clay, acids, alkalis and other salts, organic matters and sewage. First

category of the tests conducted examined the physical and chemical composition of the quarry sand. These properties are the particle size distribution based on BS 812: 2002, the specific gravity (BS 812: 1975) for assessing batch quantities; bulk density (BS 812: 2002) which enables quantities of materials for concrete to be converted from quantities by weight to volume. The second category of the test examined the slump and the compressive strength of concrete using quarry sand as fine aggregate and crushed stone as the coarse aggregate. For this purpose, two nominal mixes of 1:2:4 and 1:3:6 (cement: quarry sand: crushed stone aggregate) ratios were used. Each mix was carried out at water-cement (*W/C)* ratio of 0.50, 0.55 and 0.60.

In order to produce a workable mix batching by volume was adopted. The required quantity of quarry sand at saturated surface Dry (SSD) was measured and spread on a flat metal of about 2 square meters. The required quantity of cement was measured and mixed with the quarry sand. After even consistency the required quantity of the coarse aggregate (crushed stone also at SSD condition) as well as water was added. The constituents were thoroughly mixed until a good consistency mix was obtained. The slump and compacting factor tests were performed on each batch in accordance with provisions of BS 1881 (1996). The specimens were then cast in three layers; each layer was vibrated for 1-3 minutes. The top surfaces of the specimens were toweled flat and the moulds covered with polythene sheets in the laboratory for 24 hours, demoulded and cured in water at $27 \pm 2^0 C$ and tested at the specified periods of 7, 14, 21 and 28 days.

RESULTS AND DISCUSSIONS

The result of the particle size distribution carried out in accordance with BS 812 part 1: 2002 is presented in Table 1.

Table 1. Particle Size Distribution

Sieve size	Weight Retained (gm)	% Retained	Percentage Passing
4.75mm	99	9.9	90.1
3.35mm	122	12.2	88.9
2.36mm	123	12.3	65.6
1.18mm	192	19.2	46.4
4.25 μm	203	20.3	26.1
3.00 μm	58	5.8	30.3
150 μm	92	9.2	11.1
75 μm	75	7.5	3.6
Pan	34	3.4	0.2

The results show that to a large extent, the quarry sand is comparable to Natural River sand. More than 90% of the aggregate passed through sieve 4.75mm which places the aggregate as fine aggregate as (BS882 2002), and the assessment of the particle size distribution revealed that the aggregate is well graded.

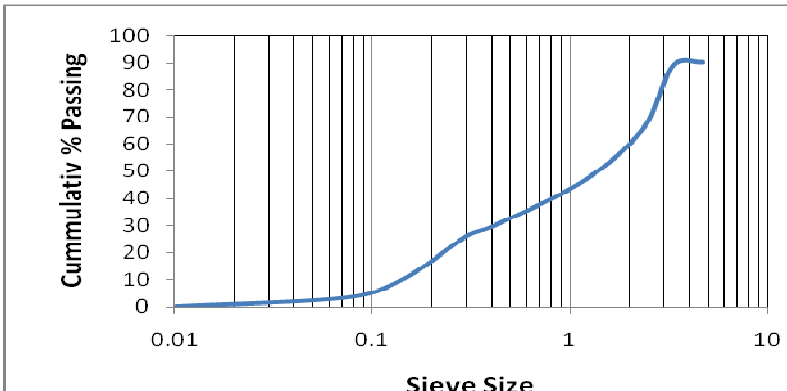

Fig. 1. Particle Size Distribution

Properties of Quarry-Sand

The apparent specific gravity of quarry sand was found to be 2.71 (Table 2). This is higher than the value obtained by Olaoye and Kamang (1999) for pumice stone. The water absorption is found to be 0.15% (Table 2). Investigations also revealed that the compacted and loose bulk densities of the aggregate as 1793kg/m^3 and 1520kg/m^3 respectively. From the test a porosity of 15.2% indicates that the mineral content rather than the voids greatly influenced the apparent specific gravity value. From the aggregate crushing value test carried out on Quarry sand, a value of 35.2% was obtained. This is higher than the value obtained by Olaoye and Kamang (1999) for pumice stone, Okpala (1990) for palm kernel. It is also higher than the value for granite which has ACV of 28.6% (Neville 1981). The value obtained suggests a higher aggregate strength even though there is no explicit relation between the crushing value and compressive strength for any given aggregate, Neville (1981). The impact value of 34.5% indicates the adequacy of the aggregate to be used in concreting (BS 812: part 3: 2002).

Table 2: Properties of Quarry –Sand.

Apparent specific gravity	2.71%
Water absorption	9.15%
Loose bulk density	1520 kg/m^3
Compacted bulk density	1793kg/m^3
Porosity	15.2%
Aggregate Crushing Value (ACV)	35.2%
Aggregate Impact Value (AIM)	34.5%

Workability and Mixes of QSC

Workability tests were carried out on QSC mixes using w/c of 0.5, 0.55 and 0.6. The result is presented in table 3.The result indicates an increase in both workability and compacting factor with increase in water- cement ratio. This is expected since higher *W/C* ratio implies more mixing water and hence higher slump and compacting factor values. The *W/C* of 0.5, 0.55, and 0.6 were adequate for QSC as there was ease of mixing, placing and compaction.

Table 3: Slump and Compacting Factor test.

Mix Proportion	W/C Ratio	Slump	Compacting Factor
	0.50	43	0.87
1:2:4	0.55	46	0.89
	0.60	52	0.91
	0.50	40	0.84
1:3:6	0.55	54	0.91
	0.60	59	0.92

Compressive Strength and Water-Cement –Ratio

The effect of *W/C* ratio on the compressive strength is shown in table 4. The plot of *W/C* and the compressive strength for both mixes (Fig. 2, 3 and 4) revealed a non linear increase in strength with *W/C*. This behaviour as reported by Neville (1981) is exhibited when compressive strength increases with *W/C* until optimum water content is reached.

Table 4: Compressive Strength test Results.

Mix	W/C	Average Strength (N/mm^2)				Average Density (Kg/m^3)			
proportion	Ratio	7 days	14 days	21 days	28 days	7 days	14 days	21 days	28 days
1:2:4	0.50	21.12	21.42	21.78	23.71	2301	2282	2282	2312
	0.55	17.64	17.93	18.23	19.17	2302	2282	2282	2292
	0.60	14.62	15.64	16.15	17.93	2263	2263	2282	2312
1:3:6	0.50	16.10	16.44	16.67	17.34	2242	2262	2252	2282
	0.55	15.41	15.20	15.63	15.85	2262	2302	2372	2282
	0.60	15.20	15.26	15.26	15.27	2272	2252	2252	2272

* All values are average of three test results

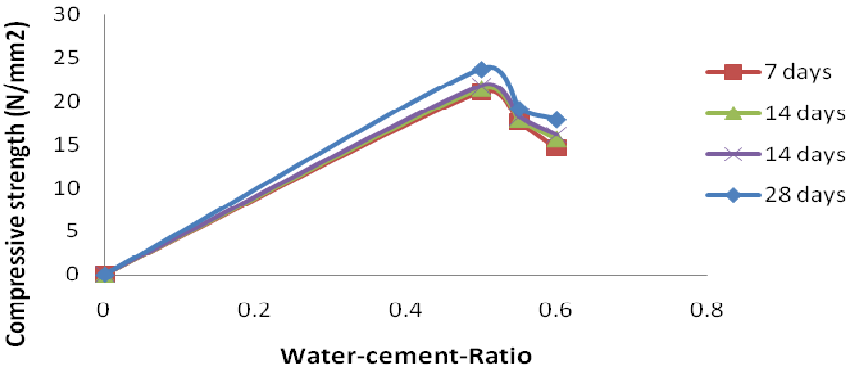

Fig. 2 Compressive strength against w/c for 1:2:4 Mix Proportion

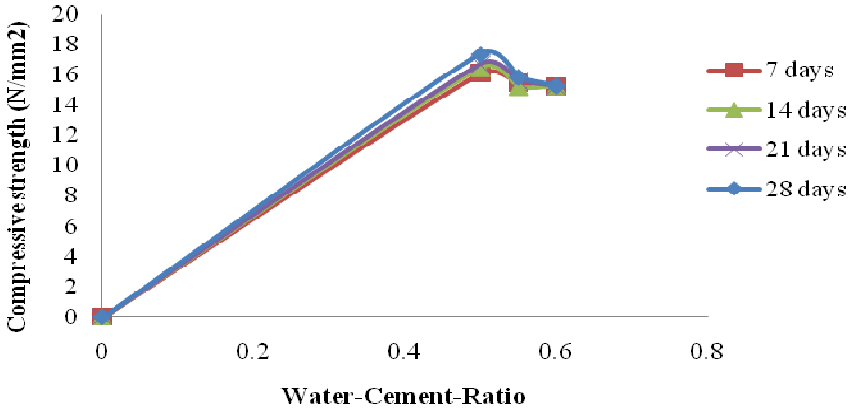

Fig. 3 Compressive Strength against w/c of 1:3:6

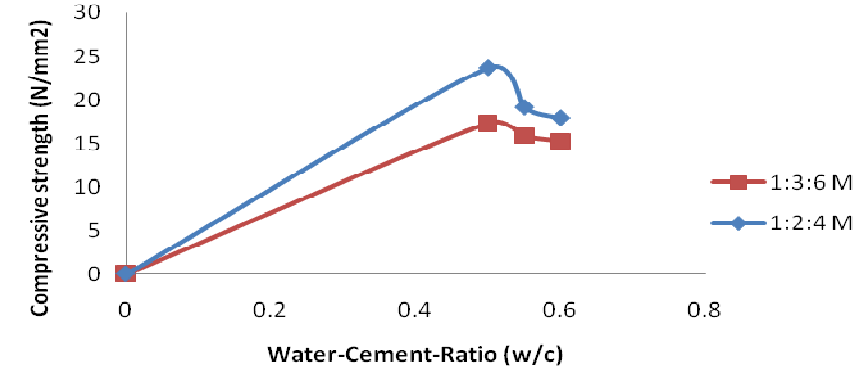

Fig. 4 Compressive Strength and w/c at 28 days Strength for Both Mixes

CONCLUSION

The Quarry sand used as fine aggregate has significant physical and chemical properties (specific gravityof 2.71, loose bulk density of 1520kg/m^{3}and compacted bulk density of 1793kg/m^3) which clasifies it as light weight aggregate, its porosity of 15.2% indicates that this high value could have influnced the specific gravity of the

material. The compressive strength for all mixes decrease with increasing water-cement-ratio. This is as would be expected (Neville 1981). The more the free water content of the fresh concrete the greater would be the volume of pores left in the hardened concrete and therefore the less the gel/space ratio and this trend is true for quarry sand concrete (QSC), and is a useful parameter in practical field construction.The compressive strength continued to incresese with curing age up to 28 days tested for each mix proportion. The compressive strength of 23.71N/mm^2 and 17.34N/mm^2 at 0.5 w/c for 1:2:4 and 1:3:6 mixes respectively are suitable for structural and masonry concrete, ASTM (1978).

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